Randomized Controlled Trial

Comparison of Local Anesthetic Concentration in Pericapsular Nerve Group (PENG) Block for Total Hip Arthroplasty Under Spinal Anesthesia: A Randomized Controlled Trial

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Background: The pericapsular nerve group (PENG) block is a novel regional technique that provides adequate postoperative analgesia without producing motor weakness during hip surgery. Objectives: We sought to compare the postoperative analgesic effectiveness of the PENG block with varying concentrations of local anesthetic in total hip arthroplasty.

Study Design: Prospective, randomized, double-blind trial registered with the ClinicalTrials.gov (NCT04900116).

Setting: Department of Anesthesiology, Istanbul University Faculty of Medicine, Istanbul, Turkey.

Methods: Ninety-one patients aged 18–80 with an American Society of Anesthesiologists Physical Status Classification of I–III undergoing total hip arthroplasty under spinal anesthesia with a PENG block were included in this study. Patients were divided into 4 groups: Group One received 20 mL of 0.5% bupivacaine; Group 2 received 20 mL of 0.25% bupivacaine; Group 3 received 20 mL of 0.125% bupivacaine; and Group 4 received 20 mL of saline as a control. Visual Analog Scale pain scores, morphine consumption, nausea, vomiting, and quadriceps weakness were evaluated at postoperative hours 0 (the end of surgery), 6, 12, 24, and 48. In addition, we recorded the first ambulation time; breakthrough morphine need; hospitalization duration; patient and surgeon satisfaction; preoperative and postoperative first month Beck-depression scores; and any complications.

Results: Groups One and 2 had significantly lower Visual Analog Scale scores and morphine consumption than the control group ($P = 0.001$ and $P = 0.001$, respectively). Quadriceps weakness was significantly higher in Group One at postoperative hour 0 ($P = 0.011$). Nausea and vomiting were significantly lower in Group One than in the other groups at postoperative hours 12 and 24 ($P = 0.007$ and $P = 0.027$, respectively). The length of hospital stay was significantly shorter in Group One than in the control group ($P = 0.048$).

Limitations: This was a single-center study with no standardized quantitative measurement method for assessing quadriceps weakness.

Conclusion: The PENG block with 20 mL of 0.5% bupivacaine in total hip arthroplasty provides effective postoperative analgesia by reducing opioid side effects and hospital stay, as evidenced by low pain scores and morphine consumption.

Key words: Total hip arthroplasty, pericapsular nerve group block, PENG, postoperative pain, analgesia

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Total hip arthroplasty (THA) is an orthopedic surgical intervention designed to improve functional recovery and quality of life in patients with end-stage degenerative osteoarthritis (1). This procedure often leads to moderate or severe pain in the early postoperative period, which can result in delayed ambulation, prolonged hospital stays, and an increased risk of thromboembolic events (2). Various analgesic methods, including opioids, nonopioid treatments, neuroaxial techniques, peripheral nerve blocks, and local infiltration analgesia are used for pain management (3).

In perioperative analgesia for hip surgery, regional anesthesia and peripheral nerve blocks have demonstrated dynamic pain control and reduce perioperative complications and postoperative opioid consumption compared to traditional intravenous opioids (4). However, achieving effective regional analgesia for hip pain is challenging due to the complex innervation of the hip joint, with standard regional techniques often associated with complications such as inadequate anesthesia, hypotension, and lower extremity weakness (5). While various peripheral nerve blocks, including lumbar plexus, fascia iliaca, and femoral nerve blocks, can be utilized, they may result in motor block to some extent, leading to delayed ambulation and functional recovery. The pericapsular nerve group (PENG) block has emerged as an effective alternative for pain management after hip-related surgeries, including fractures and hip arthroplasty, and can be integrated into multimodal postoperative pain management strategies (2,6).

The PENG block is a novel and successful regional block method that targets the articular branches of the femoral, obturator, and accessory obturator nerves, specifically the sensory branches of the femoral nerve that extend distally to the groin, preserving the sensory branches of the femoral nerve that innervate the hip joint (6). This technique offers advantages over other blocks, such as the fascia iliaca compartment block, since it does not induce quadriceps muscle weakness (7).

In various applications, different concentrations of local anesthetics, including lidocaine, ropivacaine, bupivacaine, and levobupivacaine with dexamethasone, have been used in volumes ranging from 10 mL to 40 mL (8).

In this study, we compared patients who underwent THA under spinal anesthesia with preoperative PENG blocks using different local anesthetic concentrations. Our primary outcome was morphine consumption in the first postoperative 48 hours. Secondary outcomes included Visual Analog Scale (VAS) pain scores; the need for breakthrough morphine; time to first ambulation; incidence of nausea and vomiting; quadriceps weakness; patient and surgeon satisfaction; length of hospital stay, Beck Depression Index Score; and any complications.

Methods

Recruitment and Randomization

This single-center, prospective, randomized, double-blind trial was approved by the Clinical Research Ethics Committee of the Istanbul University Faculty of Medicine and was registered with ClinicalTrials.gov (NCT04900116).

Patients aged 18–80, with an American Society of Anesthesiologists Physical Status Classification of I–III, scheduled for unilateral and elective THA under spinal anesthesia, who provided verbal and written informed consent, were included in our study. Exclusion criteria included patients unwilling to undergo regional anesthesia, those with coagulation disorders (e.g., platelet dysfunction, factor deficiencies, severe liver or kidney dysfunction), local anesthetic allergies, an infection at the intervention site, a history of chronic neuropathic pain, chronic opioid or substance use, and those unable to cooperate (e.g., psychosis or dementia).

Patients were randomized into 4 groups based on the concentration of local anesthetics used in the PENG block: 20 mL of 0.5% bupivacaine (Group One), 20 mL of 0.25% bupivacaine (Group 2), 20 mL of 0.125% bupivacaine (Group 3), and 20 mL of 0.9% saline (Group 4, control). Randomization was performed using a computer-generated randomization sequence (Microsoft Excel, Microsoft Corporation, Redmond, WA, USA). Local anesthetic concentrations were administered in a 20 mL volume for each group predetermined by the supervisor, with the actual dose unknown to the patients. The surgical team and clinicians monitoring postoperative pain were blinded to the study groups.

Ultrasound guided Block Procedures

In the operating room, standard electrocardiogram, pulse oximetry, and noninvasive blood pressure monitoring were established, followed by placement of a wide-bore intravenous cannula. Patients received intravenous midazolam (0.03 mg/kg) and intravenous fentanyl (1 μg/kg) for premedication, with oxygen delivered at 4 L/min via a face mask.

Following premedication, PENG blocks were performed under the supervision of an anesthesiologist or responsible faculty member with ultrasound guidance by senior anesthesia residents with at least 4 years of experience. With the patient supine, antisepsis was achieved using 10% povidone-iodine. A convex, low-frequency (2-5 MHz) ultrasound probe (NextGen LogiqTM-e model, GE Healthcare) was initially placed transversely over the anterior inferior iliac spine, then rotated approximately 45° counterclockwise to align with the pubic ramus. The anterior inferior iliac spine; inguinal ligament; iliopsoas muscle and tendon; femoral artery; femoral vein; and pectineus muscle were visualized (Fig. 1). Using an in-plane approach, a 22G, 100 mm peripheral block needle (Stimuplex A, B. Braun) was advanced laterally and medially between the psoas tendon anteriorly and the pubic ramus posteriorly. After negative aspiration, 20 mL of the local anesthetic or saline solution was injected into the musculofascial space, with intermittent negative aspirations observed during hydrodissection.

Anesthesia

After the PENG block, patients sat up; single-dose spinal anesthesia was administered at the L3-L4 or L4-L5 intervertebral space using an appropriate spinal needle and 10 mg–15 mg of intrathecal bupivacaine heavy. Spinal anesthesia success was confirmed using a pinprick test prior to surgery. Oxygen was administered throughout the procedure via a facemask.

Postoperative Analgesia

Patients were informed about intravenous patient-controlled analgesia prior to surgery. Patient-controlled analgesia was prepared with a 100 mL saline solution containing 30 mg morphine (0.3 mg/mL), with a basal infusion rate of the patient-controlled analgesia pump set at one mL/hr, a bolus demand dose of 6 mL, and a lockout period of 30 minutes. At the end of the surgery (postoperative hour 0), a patient-controlled analgesia pump was inserted in all patients. Pain scores using the Visual Analog Scale (VAS) (no pain is rated as 0 points and the worst imaginable pain is rated as 10 points [10 cm scale]. Patient-controlled analgesia morphine consumption (in milligrams) was recorded at postoperative hours 0, 6, 12, 24, and 48. When the VAS score was greater than 4 after each assessment, rescue analgesia with 2 mg of intravenous morphine was administered, up to a maximum of 10 mg. If the VAS score was less than 4, pain monitoring was continued. As part of multimodal analgesia, all patients received one g of intravenous acetaminophen and, if not contraindicated, a single dose of 20 mg tenoxicam (Editor's note: This medication is not approved for use by the US Food and Drug Administration) every 8 hours administered by a surgical service or intensive care nurses.

Additionally, nausea and vomiting (yes/no), time to first ambulation (hours), length of hospital stay (days), total morphine consumption (mg), breakthrough analgesic requirement (morphine, mg), and patient and surgeon satisfaction were assessed at postoperative hours 0, 6, 12, 24, and 48. Patient and surgeon satisfac-

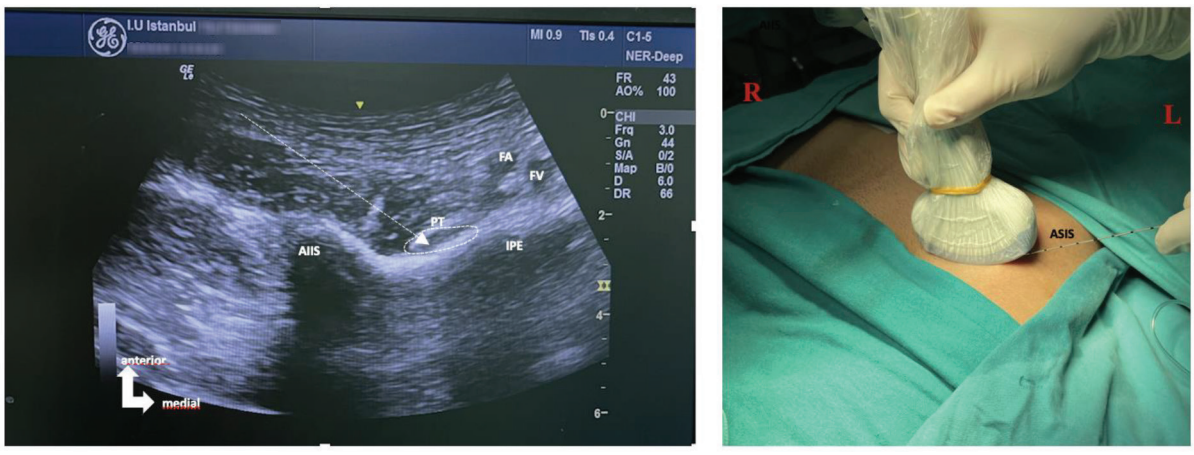


Fig. 1. *Ultrasound-guided pericapsular nerve group block.*
FA, femoral artery; FV, femoral vein; IPE, iliopubic eminence; AIIS, spina iliaca anterior inferior; PT, psoas tendon; ASIS, spina iliaca anterior superior; dashed arrow, needledirection.

tions were evaluated using a 4-point Likert scale (0-not satisfied at all, one-not satisfied, 2-satisfied, 3-very satisfied). At postoperative hours 0, 6, 12, 24, and 48 hours, quadriceps weakness (yes/no) was assessed after confirming the resolution of spinal anesthesia by examining the hip not operated on. The examining clinician supported the patient's knee from below the popliteal fossa with one hand while applying resistance to the patient's lower leg from the other side and instructed the patient to resist and perform knee extension. Knee extension limitation indicated quadriceps muscle weakness. The operated on side was evaluated first, followed by the side not operated on. Additionally, at the preoperative visit and at postoperative one month, all patients were administered the Beck Depression Index, and the scores obtained (21 questions, 0–63 points) were recorded.

Sample Size Calculation

Power and sample size software were used for power analysis to determine the sample size (G*Power, version 3.1.2, Germany). An estimated 10% change in the baseline morphine consumption values from the PENG group in the study by Alrefaey, et al (9) was used. Our study was designed for matched pairs of continuous response variables. Previous data indicated that the difference in responses between matched pairs was normally distributed, with a standard deviation of 0.8. Assuming a true difference in the mean response of 0.52, an 80% probability (power) of rejecting the null hypothesis was needed, requiring a sample size of 21 patients per group. The type Ierror probability associated with this null hypothesis test was set at 0.05. Considering a possible loss of 20%, 101 patients were included in our study.

Statistical Analysis

After collecting patients' demographic data and follow-up parameters, NCSS 2020 (NCSS Statistical Software) was used for statistical analysis. Descriptive statistics (mean, SD, median, minimum, and maximum) represented quantitative variables, while frequency and percentage were used for qualitative variables. The Shapiro–Wilk test and box plot graphs were used to assess the normal distribution of the data. A paired-sample t test was used for the intragroup evaluation of quantitative variables showing a normal distribution. For the 3 groups and above comparisons of variables that did not show a normal distribution, the Kruskal-Wallis test was used, and the Dunn test was used to identify the group causing the difference. The Friedman test was used for intragroup evaluation. The Fisher-Freeman-Halton test was used to compare qualitative data. The results were evaluated at a significance level of $P < 0.05$, with a 95% CI.

Results

In our study we assessed 101 patients who underwent unilateral THA under spinal anesthesia. Two patients who declined to participate, 3 who preferred general anesthesia, and one who used chronic opioids were excluded, leaving 95 patients who were randomized into 4 groups. Two patients with data lost during follow-up and 2 patients with block failure were excluded from the study. A total of 91 patients were included in the statistical analysis (Fig. 2). Demographic data of the patients included in the study are displayed in Table 1.

Morphine consumption at postoperative 24 hours and 48 hours differed significantly among the groups ($P = 0.001$). At postoperative 24 hours, Group 4 had a significantly higher morphine consumption than Groups One, 2, and 3 ($P = 0.001$, $P = 0.002$, and $P = 0.021$, respectively). At postoperative 48 hours, Group 4's morphine consumption remained significantly higher than that in Groups One and 2 ($P = 0.001$ for both). Additionally, Group 3 had a significantly higher morphine consumption than Group One ($P = 0.025$) (Table 2).

Group 4 had significantly higher VAS scores than Groups One and 2 ($P = 0.001$ for both); Group 3 had significantly higher VAS scores than Group One ($P=0.001$). There was a significant difference in VAS score changes from postoperative hour 0 to hour 12 among the groups ($P = 0.001$), with Group 4 showing a significantly greater change than groups One, 2, and 3 ($P = 0.003$, $P = 0.004$, and $P = 0.018$, respectively) (Table 3).

There was a significant difference in quadriceps weakness rates at postoperative hour 0 among the groups ($P = 0.011$), with Group One exhibiting higher rates than groups 2, 3, and 4. No significant differences were found at postoperative hours 6, 12, 24, and 48 (Table 4).

There was no statistically significant difference in the time to the first ambulation among the groups. The amount of breakthrough morphine required by the patients in Group 4 was significantly higher compared to those in groups One, 2, and 3 ($P = 0.001$ for each comparison). Additionally, patients in Group 3 required significantly more breakthrough morphine than those in Group One ($P = 0.010$). Additionally, nausea and

vomiting were significantly lower in Group One than in the other groups at the postoperative hours 12 and 24 (P = 0.007 and P = 0.027, respectively). There was a statistically significant difference in the hospital stay length among the groups (P = 0.028), with Group 4 patients having a significantly longer hospital stay than Group One (P = 0.048) (Table 5).

The statistical data presented in Table 6 illustrate the relationships and differences between the parameters related to breakthrough morphine, nausea, and vomiting at postoperative hour 12, as well as VAS scores, and morphine consumption at the postoperative hours 6, 12, 24, and 48. All analyses were conducted using a Repeated General Linear Model, with the significance level set at $P < 0.01$. The odds ratio for breakthrough morphine was 0.340 (CI, 0.282–0.399; P = 0.001), indicating that the need for breakthrough morphine was significantly lower. Significant reductions in VAS scores and morphine consumption were observed at postoperative hours 6, 12, 24, and 48 ($P < 0.001$).

Discussion

Regional analgesic techniques that provide sufficient analgesia without affecting muscle strength, while reducing opioid-related side effects and accelerating postoperative recovery, are essential in hip surgery (10). Our study demonstrates that the PENG block provides effective postoperative analgesia in total hip arthroplasty, particularly at higher local anesthetic concentrations. Compared to the control group, 0.5% bupivacaine significantly reduced morphine consumption and pain scores, while also minimizing opioid-related side effects such as nausea and vomiting. Furthermore, despite a transient quadriceps weakness observed at the 0-hour mark, overall motor function was well-preserved, and functional outcomes such as ambulation time remained comparable across groups.

Meta-analyses evaluating the efficacy of the PENG block post hip surgery have shown mixed results. Wang, et al (11) reported a significant reduction in 24-hour morphine consumption compared to the fascia iliaca compartment block, whereas Yu, et al (12) found no significant difference in opioid use between the PENG block and control groups. These discrepancies may be attributed to variations in study design; anesthetic concentration and volume; or patient populations. Nevertheless, several studies have emphasized the potential benefits of the PENG block in reducing opioid consumption following hip surgery, likely due to its targeted sensory blockade and effective periarticular coverage without substantial motor impairment.

Del Buono, et al (13) defined the PENG block as

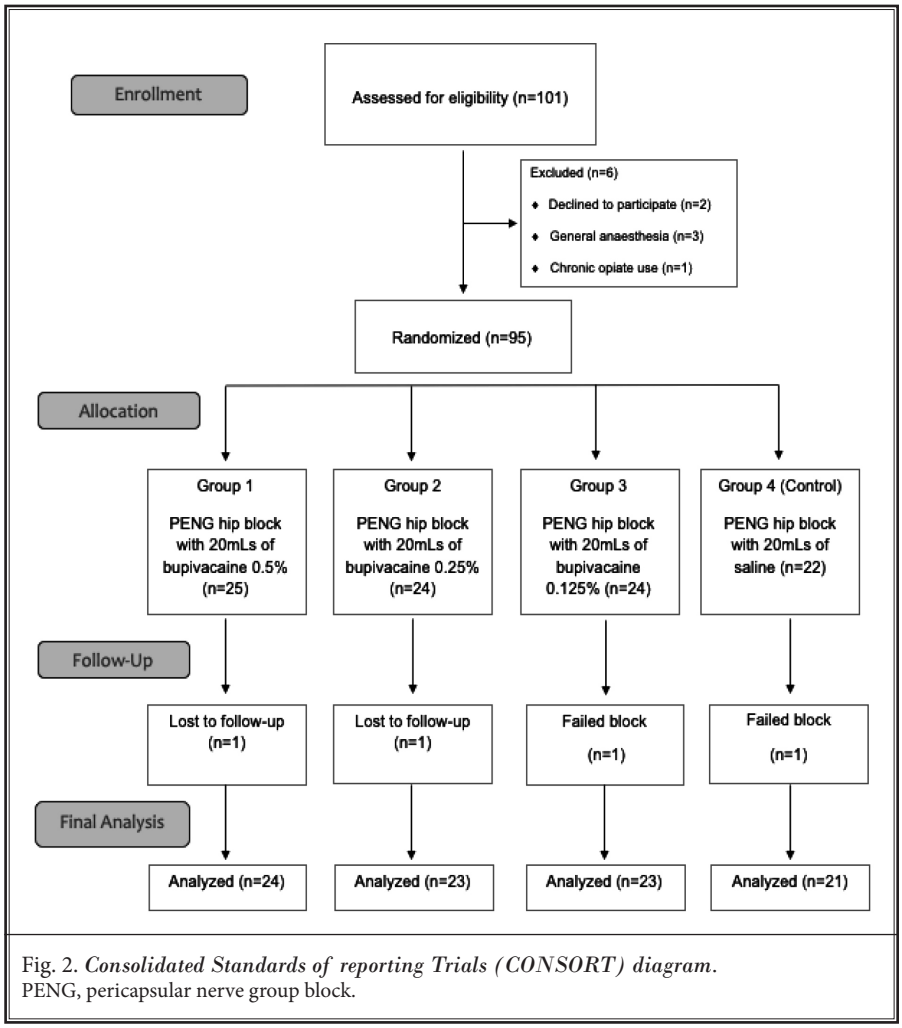


Fig. 2. *Consolidated Standards of reporting Trials (CONSORT) diagram.*
PENG, pericapsular nerve group block.

an opioid-sparing analgesic strategy for the hip, while Huda, et al (4) reported reduced opioid consumption within the first 24 hours post PENG block. In our study, the PENG block with all concentrations of local anesthetic showed an opioid-sparing effect within the first postoperative 24 hours compared to the control group. Specifically, the 0.5% and 0.25% bupivacaine groups demonstrated reduced morphine consumption at postoperative 48 hours, while the control group, and the 0.125% bupivacaine group showed significantly higher total and breakthrough morphine requirements than the 0.5% bupivacaine group, indicating that 0.5% bupivacaine provides optimal opioid-sparing analgesia. Furthermore, the lower incidence of nausea and vomiting observed in the 0.5% bupivacaine group indicated a reduction in opioid-related side effects due to decreased morphine consumption.

Our study also revealed that the PENG block significantly reduces postoperative hour 12 VAS scores across all local anesthetic concentrations compared to the control group, indicating its early effectiveness in managing postoperative pain. This aligns with Chung, et al (14) who observed reduced pain scores in the first postoperative 6 hours with a PENG block using 25 mL of 0.5% ropivacaine compared to their control group, emphasizing the early postoperative analgesic efficacy of the block. However, their study involved patients under general anesthesia, which may explain the short-lived analgesic effect of the block. In our study, the significantly lower VAS scores in the 0.5% bupivacaine group than in the 0.125% bupivacaine group at postoperative 48 hours indicates that a higher local anesthetic concentration results in lower pain scores.

Comparisons with studies involving the suprainguinal fascia iliaca compartment block (15), fascia iliaca compartment block (16), or femoral nerve block (17) indicate that the PENG block preserves quadriceps muscle strength better because it does not block the motor branches of the femoral nerve. In our study, quadriceps weakness was significantly higher only in the 0.5% bupivacaine group at postoperative hour 0. Although this suggests that a high local anesthetic concentration may affect early postoperative muscle strength, weakness was later found to

Table 1. *Study patients' baseline demographic and clinical characteristics.*

		n (%)
Gender	Women	56 (61.5)
	Men	35 (38.5)
Age (yrs)	Mean ± SD	57.18 ± 12.27
	Median (Min-Max)	57 (29-80)
Height (cm)	Mean±SD	163.53 ± 7.97
	Median (Min-Max)	163 (150-180)
Weight (kg)	Mean±SD	76.35 ± 12.80
	Median (Min-Max)	76 (45-115)
BMI (kg/m^2)	Mean±SD	28.61 ± 4.76
	Median (Min-Max)	28.03 (19.15-39.96)
ASA Physical Status Classification	ASA I	18 (19.8)
	ASA II	58 (63.7)
	ASA III	15 (16.5)

ASA, American Society of Anesthesiologists; BMI, Body Mass Index

Table 2. *Total postoperative 48 hours morphine consumption across study groups.*

Morphine Consumption (mg)		Group One (n = 24)	Group 2 (n = 23)	Group 3 (n = 23)	Group 4 (n = 21)	Total (n = 91)	*P*
Postop hour 0	Mean ± SD	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	[c]1.000
	Median (Min-Max)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	
Postop hour 6	Mean ± SD	5.30 ± 2.37	5.75 ± 2.17	6.11 ± 2.89	8.89 ± 3.1	6.45 ± 2.94	[c]0.001**
	Median (Min-Max)	5.1 (1.7-10.2)	5.2 (3.6-12.5)	5.5 (1.8-13.4)	8.8 (3.6-16.7)	5.6 (1.7-16.7)	
Postop hour 12	Mean ± SD	8.85 ± 3.34	9.2 ± 3.19	10.01 ± 4.24	14.7 ± 5.2	10.58 ± 4.59	[c]0.001**
	Median (Min-Max)	8.8 (3.6-14.4)	7.8 (6.1-16.5)	9.1 (5.3-19.3)	14.2 (6-25.7)	9.5 (3.6-25.7)	
Postop hour 24	Mean ± SD	13.98 ± 4.20	14.37 ± 4.13	15.6 ± 5.79	20.21 ± 4.98	15.92 ± 5.32	[c]0.001**
	Median (Min-Max)	13.6 (7.2-21.9)	13.2 (9.4-23)	15.1 (8.4-28.9)	19.8 (12.6-30)	15.5 (7.2-30)	
Postop hour 48	Mean ± SD	19.00 ± 3.62	20.41 ± 5.11	23.68 ± 5.23	27.79 ± 3.66	22.57 ± 5.54	[c]0.001**
	Median (Min-Max)	18.8 (13.5-25.7)	18 (14-29.9)	24.3 (15.2-32)	28.2 (20.6-34)	22.8 (13.5-34)	
	P	[d]0.001**	[d]0.001**	[d]0.001**	[d]0.001**		

[c]Kruskal Wallis Test & Dunn-Bonferroni Test
[d]Friedman Test & Wilcoxon Corrected Pairwise Comparisons
**$P < 0.01$ *$P < 0.05$

Table 3. *Comparison of postoperative (postop) Visual Analog Scale (VAS) pain scores among groups.*

VAS		Group One (n = 24)	Group 2 (n = 23)	Group 3 (n = 23)	Group 4 (n = 21)	Total (n = 91)	*P*
Postop hour 0	Mean ± SD	1.08 ± 1.59	1.61 ± 1.78	1.78 ± 1.78	2.57 ± 1.83	1.74 ± 1.79	[c]0.064
	Median (Min-Max)	0 (0-5)	1 (0-5)	2 (0-5)	2 (0-7)	2 (0-7)	
Postop hour 6	Mean ± SD	3.54 ± 1.06	3.74 ± 1.86	3.91 ± 1.41	6.81 ± 1.47	4.44 ± 1.96	[c]0.001**
	Median (Min-Max)	3.5 (1-5)	4 (0-7)	4 (0-6)	7 (5-10)	4 (0-10)	
Postop hour 12	Mean ± SD	3.13 ± 1.39	3.48 ± 1.53	4.13 ± 1.32	6.95 ± 1.56	4.35 ± 2.06	[c]0.001**
	Median (Min-Max)	3 (0-5)	3 (1-6)	4 (1-7)	7 (4-10)	4 (0-10)	
Postop hour 12	Mean ± SD	2.46 ± 1.22	2.61 ± 1.44	3.96 ± 1.49	4.86 ± 1.01	3.43 ± 1.62	[c]0.001**
	Median (Min-Max)	3 (0-4)	3 (0-6)	4 (0-6)	5 (3-8)	3 (0-8)	
Postop hour 48	Mean ± SD	1.38 ± 1.31	1.74 ± 1.76	3.17 ± 1.11	4.24 ± 0.83	2.58 ± 1.72	[c]0.001**
	Median (Min-Max)	1 (0-4)	2 (0-5)	3 (2-5)	4 (3-6)	3 (0-6)	
	P	[d]0.001**	[d]0.001**	[d]0.001**	[d]0.001**		

[c]Kruskal Wallis Test & Dunn-Bonferroni Test
[d]Friedman Test & Wilcoxon Pairwise Comparisons

Table 4. *Incidence of postoperative (postop) quadriceps muscle weakness in the study groups.*

Quadriceps Weakness		Group One (n = 24)	Group 2 (n = 23)	Group 3 (n = 23)	Group 4 (n = 21)	Total (n = 91)	[a]*P*
Postop hour 0	No (%)	0 (0)	7 (30.4)	2 (8.7)	2 (9.5)	11 (12.1)	0.011*
	Yes (%)	24 (100)	16 (69.6)	21 (91.3)	19 (90.5)	80 (87.9)	
Postop hour 6	No (%)	5 (20.8)	6 (26.1)	5 (21.7)	4 (19)	20 (22)	0.969
	Yes (%)	19 (79.2)	17 (73.9)	18 (78.3)	17 (81)	71 (78)	
Postop hour 12	No (%)	7 (29.2)	9 (39.1)	7 (30.4)	9 (42.9)	32 (35.2)	0.751
	Yes (%)	17 (70.8)	14 (60.9)	16 (69.6)	12 (57.1)	59 (64.8)	
Postop hour 24	No (%)	21 (87.5)	18 (78.3)	17 (73.9)	17 (81)	73 (80.2)	0.696
	Yes (%)	3 (12.5)	5 (21.7)	6 (26.1)	4 (19)	18 (19.8)	
Postop hour 48	No (%)	23 (95.8)	21 (91.3)	22 (95.7)	21 (100)	87 (95.6)	0.848
	Yes (%)	1 (4.2)	2 (8.7)	1 (4.3)	0 (0)	4 (4.4)	

[a]Fisher Freeman Halton Test
*$P < 0.05$

be similar to that in the control group, possibly because of the diminishing effect of the block. Additionally, given the surgical clinic's goal of ambulating patients on post-surgery day one, the clinical significance of weaknesses that occur in the early postoperative hours is negligible.

Kukreja, et al (18) reported that a PENG block in patients undergoing THA under spinal anesthesia reduced opioid requirements and improved the quality of postoperative recovery. Similarly, in our study, the group receiving 0.5% bupivacaine exhibited lower pain scores, decreased morphine consumption, and consequently, a shorter hospital stay than the control group, which contributed to a reduction of opioid-related side effects. Increasing evidence suggests that the implementation of Enhanced Recovery After Surgery (ERAS) protocols leads to a reduction in hospital stay and postoperative complications (19). The similarity in the first ambulation times among the groups was associated with the effective preservation of motor function using the PENG block in our clinic, coupled with routine ambulation and early physiotherapy practices aligned with ERAS-targeted surgery. While the average hospital stay post THA is typically one day or less in some health care systems such as the United States, patients in our institution generally remain hospitalized for 3 to 4 days. This longer stay reflects our routine protocols, which include supervised early ambulation, comprehensive physiotherapy, patient education, and adherence to local clinical guidelines aimed at optimizing recovery and patient safety.

Table 5. *Comparison of time to first ambulation, breakthrough morphine use, hospital length of stay, and incidence of nausea and vomiting by groups.*

		Group One (n = 24)	Group 2 (n = 23)	Group 3 (n = 23)	Group 4 (n = 21)	Total (n = 91)	[c]*P*
First ambulation time (postop hour)	Mean ± SD	29.63 ± 10.93	29.61 ± 11.33	29.83 ± 11.15	35.86 ± 10.6	31.11 ± 11.14	0.184
	Median (Min-Max)	24 (18-50)	24 (18-48)	24 (16-48)	40 (20-48)	24 (16-50)	
Breakthrough morphine (mg)	Mean ± SD	0.5 ± 0.88	1.83 ± 1.19	2.43 ± 2.00	6.29 ± 1.45	2.66 ± 2.55	0.001**
	Median (Min-Max)	0 (0-2)	2 (0-4)	2 (0-6)	6 (4-8)	2 (0-8)	
Length of hospital stay (days)	Mean ± SD	4.63 ± 3.46	4.43 ± 2.45	4.13 ± 1.18	4.86 ± 0.91	4.51 ± 2.26	0.028*
	Median (Min-Max)	4 (3-20)	4 (3-15)	4 (3-7)	5 (3-6)	4 (3-20)	

[c]Kruskal Wallis Test & Dunn-Bonferroni Test
**$P < 0.01$ *$P < 0.05$

Nausea and Vomiting		Group One (n = 24)	Group 2 (n = 23)	Group 3 (n = 23)	Group 4 (n = 21)	Total (n = 91)	[a]*P*
Postop hour 0	No (%)	23 (95.8)	20 (87)	19 (82.6)	18 (85.7)	80 (87.9)	0.568
	Yes (%)	1 (4.2)	3 (13)	4 (17.4)	3 (14.3)	11 (12.1)	
Postop hour 6	No (%)	16 (66.7)	15 (65.2)	15 (65.2)	12 (57.1)	58 (63.7)	0.920
	Yes (%)	8 (33.3)	8 (34.8)	8 (34.8)	9 (42.9)	33 (36.3)	
Postop hour 12	No (%)	23 (95.8)	17 (73.9)	14 (60.9)	12 (57.1)	66 (72.5)	0.007**
	Yes (%)	1 (4.2)	6 (26.1)	9 (39.1)	9 (42.9)	25 (27.5)	
Postop hour 24	No (%)	24 (100)	18 (78.3)	17 (73.9)	16 (76.2)	75 (82.4)	0.027*
	Yes (%)	0 (0)	5 (21.7)	6 (26.1)	5 (23.8)	16 (17.6)	
Postop hour 48	No (%)	24 (100)	23 (100)	19 (82.6)	21 (100)	87 (95.6)	0.008**
	Yes (%)	0 (0)	0 (0)	4 (17.4)	0 (0)	4 (4.4)	

[a]Fisher Freeman Halton Test
**$P < 0.01$ *$P < 0.05$

Table 6. *Correlation analysis of breakthrough morphine, nausea and vomiting, Visual Analog Scale (VAS) pain scores, and total morphine consumption within groups.*

	P	Odds Ratio	95% CI	
			Lower	Upper
Breakthrough morphine (mg)	0.001	0.340	0.282	0.399
Nausea and vomiting Postop hour 12	0.002	0.813	0.317	1.309
VAS Postop hour 6	< 0.001	0.316	0.216	0.417
VAS Postop hour 12	< 0.001	0.351	0.263	0.438
VAS Postop hour 24	< 0.001	0.404	0.286	0.522
VAS Postop hour 48	< 0.001	0.421	0.317	0.526
Morphine consumption Postop hour 6	< 0.001	0.157	0.084	0.230
Morphine consumption Postop hour 12	< 0.001	0.106	0.060	0.152
Morphine consumption Postop hour 24	< 0.001	0.086	0.046	0.126
Morphine consumption Postop hour 48	< 0.001	0.120	0.086	0.154

Repeated General Linear Model; **$P < 0.01$

In a review by Kaur, et al (20) and a meta-analysis by Wang, et al (11), further studies are required to determine the ideal local anesthetic dose and volume. We used a 20 mL volume for the block because higher volumes, such as 30 mL, have been associated with quadriceps weakness developing and increased femoral nerve involvement, which can hinder early rehabilitation (6,21,22).

Compared with quadratus lumborum and lumbar plexus blocks, the PENG block offers significant advantages, including its suitability for supine positioning, a safer injection site away from neurovascular structures, and enhanced safety for patients on anticoagulants (18,23).

Using ultrasound guidance for the block allowed us to preserve vascular

and neural structures, thereby preventing potential complications. Although larger patient groups are needed, it can be stated that the PENG block is a reliable block in terms of complications.

The limitations of our study include its single-center design and absence of a standardized quantitative measurement method for assessing quadriceps weakness.

Conclusions

We believe that the PENG block using 20 mL of 0.5% bupivacaine in THA surgeries provides ideal postoperative analgesia by reducing opioid-related side effects, decreasing hospital stay, and achieving low pain scores and morphine consumption, despite the occurrence of early quadriceps weakness.

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